Sensor Update

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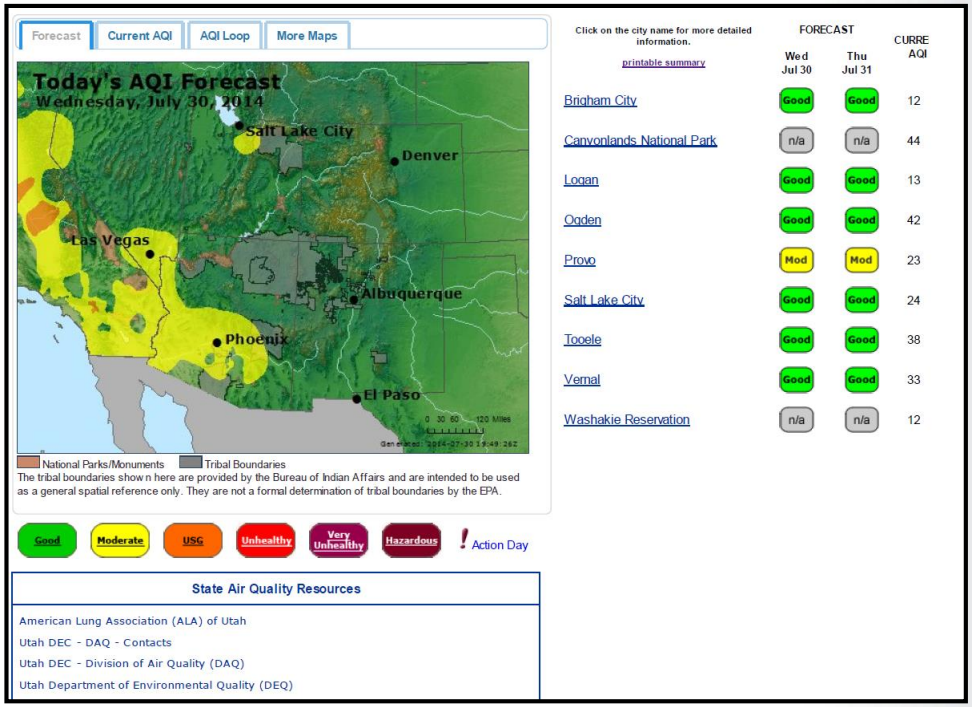
U.S. Environmental Protection Agency
Office of Research and Development

2014 National Ambient Air Monitoring Conference
Atlanta, GA
August 11-14, 2014

Traditional Air Monitoring Paradigm

- Expensive instruments (> $20K/unit)
- Specialized training required
- Large physical footprint
- Large power draw
- Lifetime of 10+ years



- Government-provided data
- Air Quality Index (AQI) provided on broad time and spatial scales

Typical Low Cost Monitor

- Inexpensive instruments ($100-$5,000)
- Highly portable and easy to operate
- Does not require specialized training to operate
- Low operation costs (replace or recharge batteries)
- Lifetime between 1-2 years

High Interest by public for more information

Public demand for more personalized information.

What about….

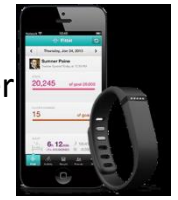
- *My* exposure?
- *My* neighborhood?
- *My* child?

New Technologies

Technology advances are supporting a shift towards new ways of measuring and communicating air quality information

Smartphone / Tablet in widespread use

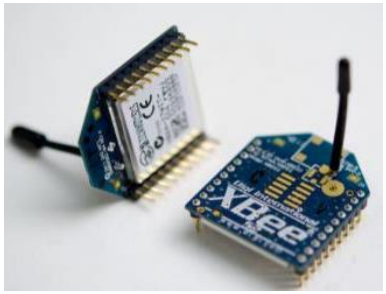
e.g., fitbit activity tracker



Miniaturized environmental sensors

Introduction of low cost controls and communications

e.g., Arduino microprocessor



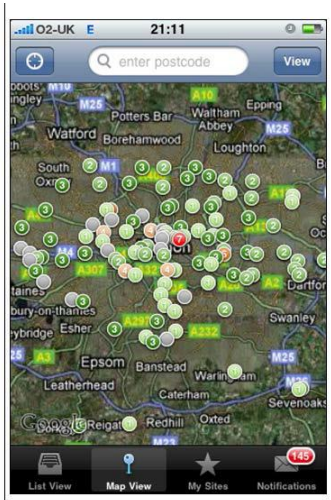
Crowd-funding supporting do-it-yourself (DIY) innovation

e.g., Kickstarter

Web-based Portals

Emerging data-viewing/communication apps

airalliancehouston.org



londonair.org.uk/iphone

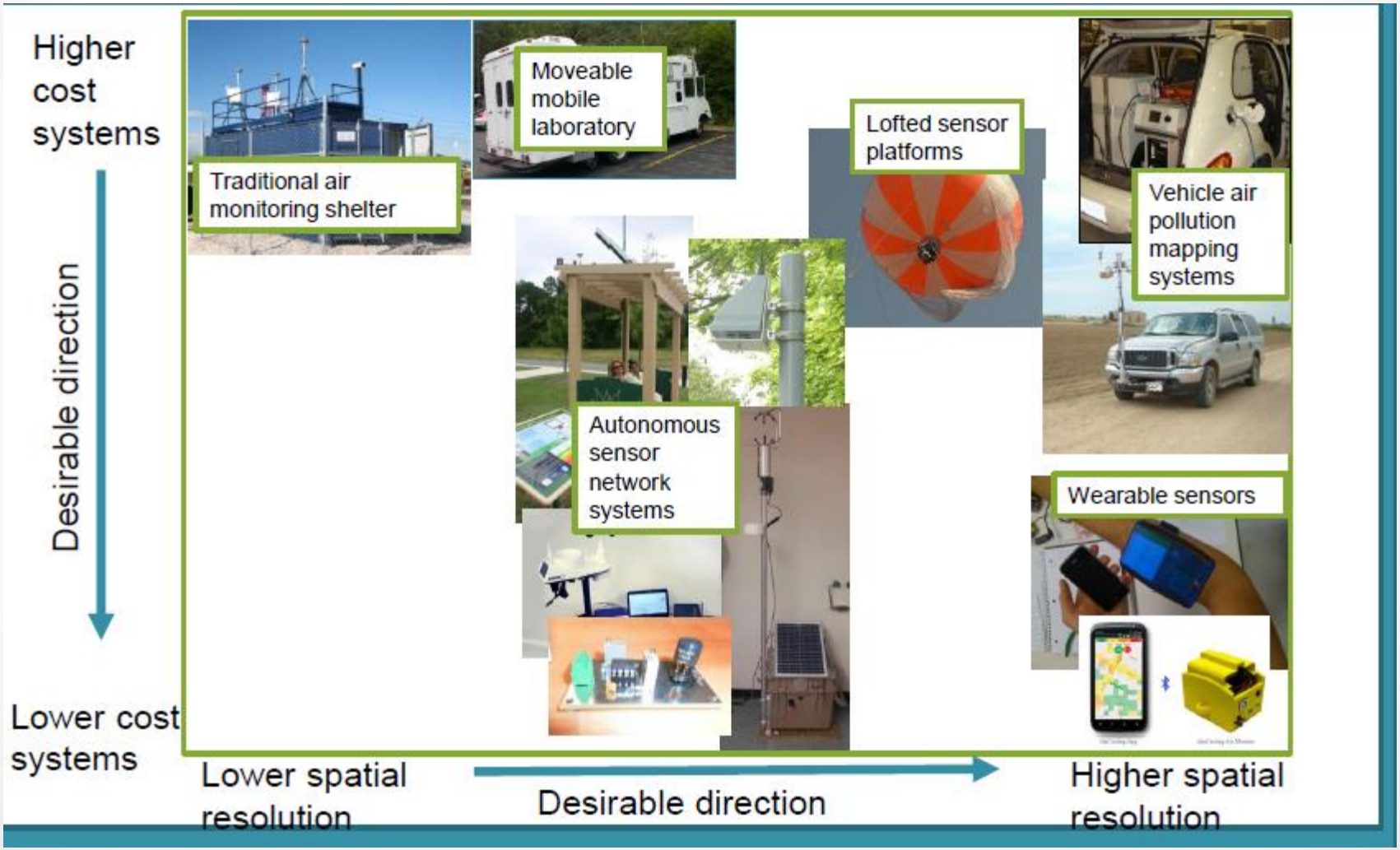
AirCasting App

aircasting.org

AirCasting Air Monitor

airqualityegg.org

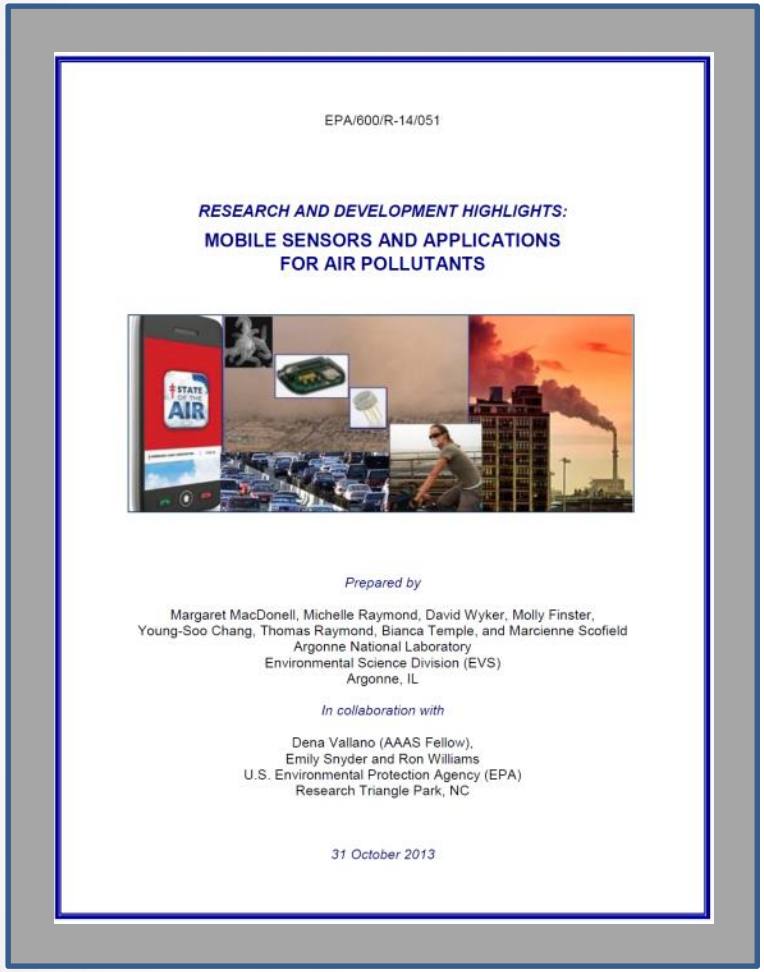
Innovation in Air Monitoring



Peer-Reviewed Articles

Snyder et al. (2013) Changing the Paradigm of Air Pollution Monitoring, ES&T, 47, 11369-11377.

Intensive Literature and Market Surveys



EPA/600/R-14/051

RESEARCH AND DEVELOPMENT HIGHLIGHTS:

MOBILE SENSORS AND APPLICATIONS FOR AIR POLLUTANTS

Prepared by

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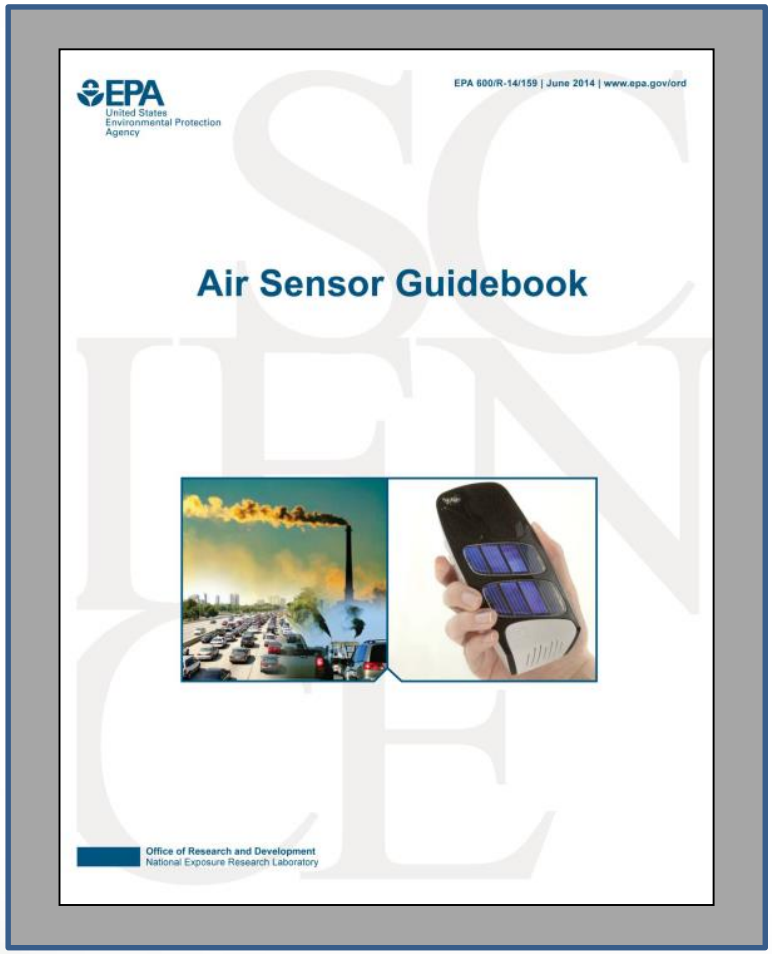
31 October 2013

Overview of research relevant to mobile sensing of air pollution.

http://www.epa.gov/airscience/next-generation-air-measuring.htm

Air Sensor Guidebook



Defines what sensor users need to understand in order to collect meaningful air quality data.

http://www.epa.gov/airscience/docs/air-sensor-guidebook.pdf

Sensor Evaluation MCRADAs

www.epa.gov/airscience

AIR CLIMATE & ENERGY RESEARCH PROGRAM
BUILDING A SCIENTIFIC FOUNDATION FOR SOUND ENVIRONMENTAL DECISIONS

Sensor and Apps Evaluation Opportunity

WHAT: EPA offers technology developers the opportunity to send in your sensor for evaluation in a controlled laboratory setting.

WHEN: Nominate your device by June 30, 2012
Testing to occur July – September, 2012

HOW: Device developers should submit a statement of interest to EPA by June 30, 2012 providing basic information about their device. Due to capacity constraints, EPA will accept a limited number (~10) devices for evaluation over a range of pollutant concentrations and environmental conditions (e.g. humidity and potential interferences). Participants will be invited to visit the EPA lab in early July to discuss their instruments, the evaluation protocol, and receive a tour of the facility. Following the completion of the evaluation each participant will receive information on the performance of their device under known environmental conditions.

QUESTIONS or Point of Contact: Ron Williams, 919-541-2957, williams.ronald@epa.gov

SELECTION CRITERIA: Devices receiving the highest consideration:

- have the technical feasibility to measure NO_2 and/or O_3 at environmentally relevant concentrations,
- have some preliminary data on expected performance characteristics,
- have not previously undergone standardized evaluations under known challenge test conditions by any party, and
- represent highly portable sensor and smart phone type applications featuring continuous measurement capabilities.

Background/Description:

- Open call for potential collaboration
- Focus on NO_2 and O_3
- 9 research groups nominated devices for evaluation
- Formal cooperative agreements established
- Not FRM/FEM evaluations

Feedback provided to developers:

- General performance of device
- Observations on operation
- Validated non-summarized data

➢ EPA's intent was not to compare one specific device with another

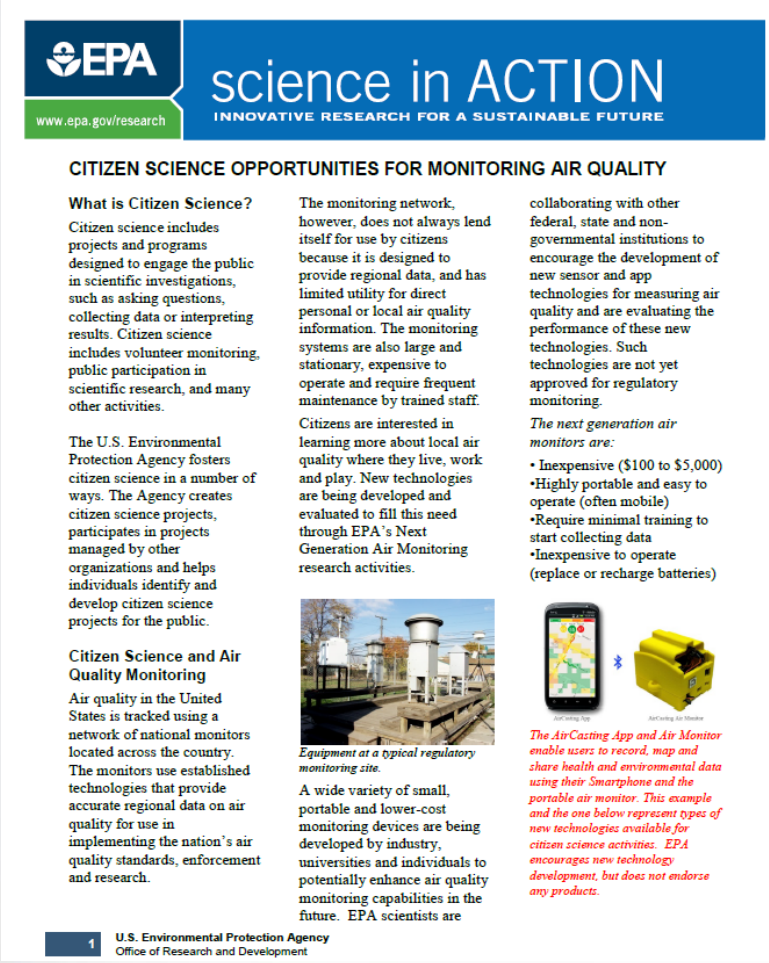
➢ EPA recognized confidential nature of technologies

Sensor Evaluation Report

Summary of MCRADA evaluation of NO_2 and O_3 sensors.

http://www.epa.gov/airscience/docs/sensor-evaluation-report.pdf

Citizen Science Fact Sheet



EPA science in ACTION
www.epa.gov/research
INNOVATIVE RESEARCH FOR A SUSTAINABLE FUTURE

CITIZEN SCIENCE OPPORTUNITIES FOR MONITORING AIR QUALITY

What is Citizen Science?

Citizen science includes projects and programs designed to engage the public in scientific investigations, such as asking questions, collecting data or interpreting results. Citizen science includes volunteer monitoring, public participation in scientific research, and many other activities.

The U.S. Environmental Protection Agency fosters citizen science in a number of ways. The Agency creates citizen science projects, participates in projects managed by other organizations and helps individuals identify and develop citizen science projects for the public.

Citizen Science and Air Quality Monitoring

Air quality in the United States is tracked using a network of national monitors located across the country. The monitors use established technologies that provide accurate regional data on air quality for use in implementing the nation's air quality standards, enforcement and research.

The monitoring network, however, does not always lend itself for use by citizens because it is designed to provide regional data, and has limited utility for direct personal or local air quality information. The monitoring systems are also large and stationary, expensive to operate and require frequent maintenance by trained staff.

Citizens are interested in learning more about local air quality where they live, work and play. New technologies are being developed and evaluated to fill this need through EPA's Next Generation Air Monitoring research activities.

Equipment at a typical regulatory monitoring site.

A wide variety of small, portable and lower-cost monitoring devices are being developed by industry, universities and individuals to potentially enhance air quality monitoring capabilities in the future. EPA scientists are collaborating with other federal, state and non-governmental institutions to encourage the development of new sensor and app technologies for measuring air quality and are evaluating the performance of these new technologies. Such technologies are not yet approved for regulatory monitoring.

The next generation air monitors are:

- Inexpensive ($100 to $5,000)
- Highly portable and easy to operate (often mobile)
- Require minimal training to start collecting data
- Inexpensive to operate (replace or recharge batteries)

The AirCasting App and Air Monitor enable users to record, map and share health and environmental data using their Smartphone and the portable air monitor. This example and the one below represent types of new technologies available for citizen science activities. EPA encourages new technology development, but does not endorse any products.

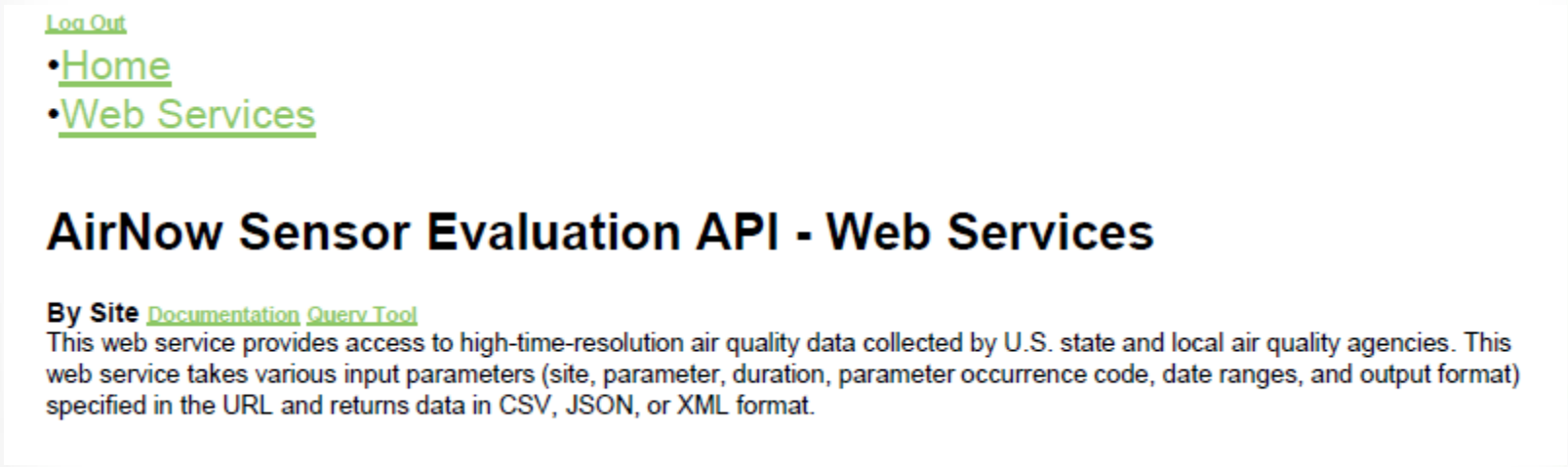
1 U.S. Environmental Protection Agency
Office of Research and Development

Defines roles of low cost sensors for citizen science

http://epa.gov/research/priorities/docs/citizen-science-fact-sheet.pdf

AirNow Sensor Evaluation Application Program Interface (API)

Sensor Evaluation API


Log Out

•Home

•Web Services

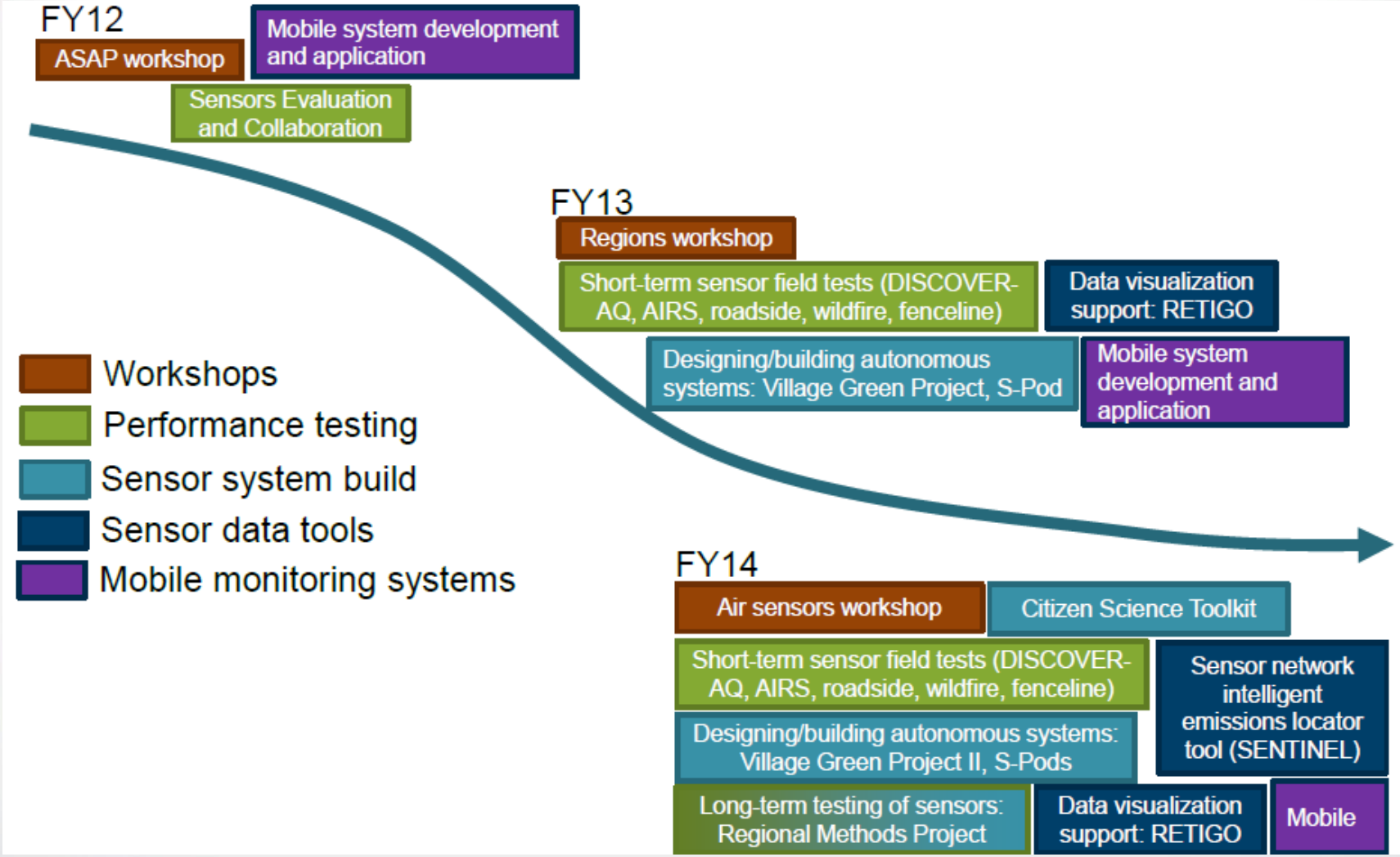
AirNow Sensor Evaluation API - Web Services

By Site Documentation Query Tool

This web service provides access to high-time-resolution air quality data collected by U.S. state and local air quality agencies. This web service takes various input parameters (site, parameter, duration, parameter occurrence code, date ranges, and output format) specified in the URL and returns data in CSV, JSON, or XML format.

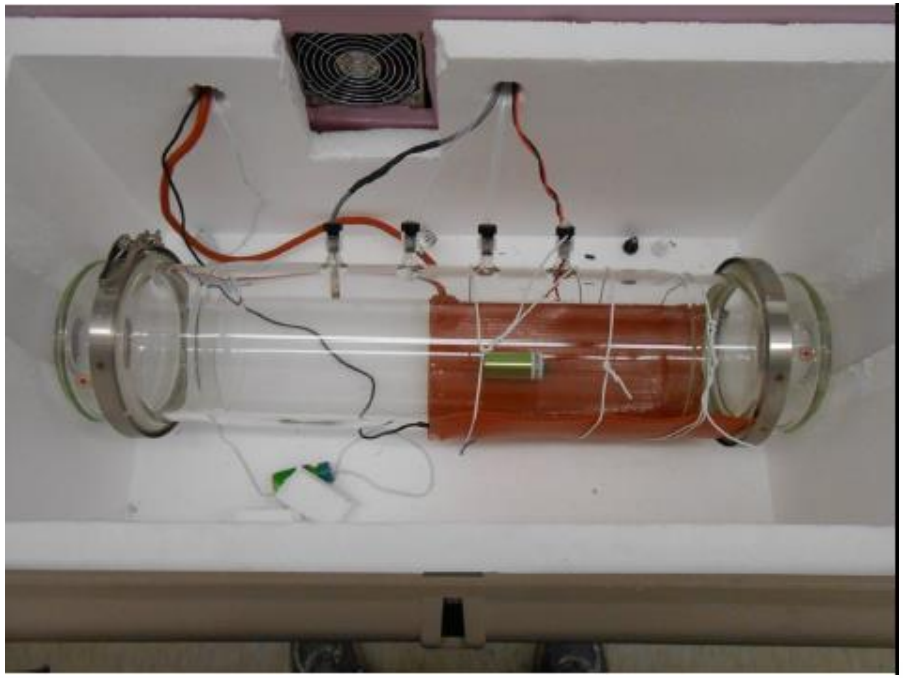
http://smallsensors.sonomatechdata.com/

Next-generation air monitoring R&D has been a rapidly moving area



Sensor performance evaluation: lab and field

Example: CairClip Sensor for NO_2+O_3



Typical O_3 and NO_2 Sensor Performance Characteristics

	Conditions	Response	Linearity	Precision	LDL	IDL	Res low	Res High	Lag Time	Rise Time	SO2 int	O3 Int	NO2 Int
		kOhm/ppb	R^2	ppb	ppb	ppb	ppb	ppb	minutes	minutes	ppb	ppb	ppb
O3	Normal	0.4186	0.9824	10.3	15.6	11.8	8.3	14.1	1	5	7.5	NA	32.2
	Hot	0.2492	0.9933	13.6	12.4	18.1	6.8	37.7	1	6			
	Humid	0.3383	0.9774	2.6	12.4	16	5.9	4	1	4			
	Cold	0.5484	0.9772	7.2	9.8	11.3	2.6	6.1	1	3			
NO2	Normal	0.6362	0.9972	1.2	15	9.5	1.8	2.3	1	5	19.5	off scale	NA
	Hot	0.0995	0.9919	6.4	13.6	24	5.7	8.1	1	20			
	Humid	0.4526	0.9937	7.4	17.7	22.8	2.7	5.2	1	7			
	Cold	3.4208	0.9917	7.5	10.2	5.2	0.8	6.8	1	6			
CFR O3	NA	NA	NA	10	10	10	5	5	20	15	20	20	20
CFR NO2	NA	NA	NA	10	10	10	5	5	20	15	20	20	20

Widely Variable

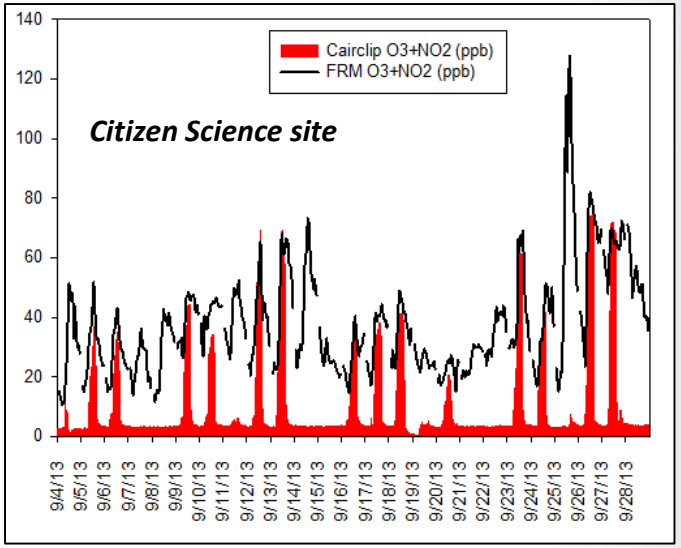
Widely Variable

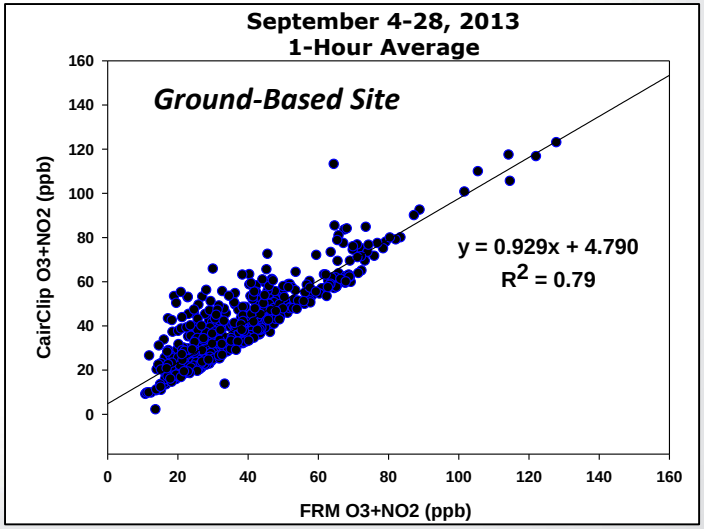
Sensor performance evaluation: lab and field

DISCOVER-AQ Study Houston, TX (Sept. 2013)

- Citizen science: small NO_2+O_3 and NO_2 sensors deployed at 7 local schools
- Sensor data compared to reference analyzer data
- Low-cost sensors performed well

CairClip Sensor



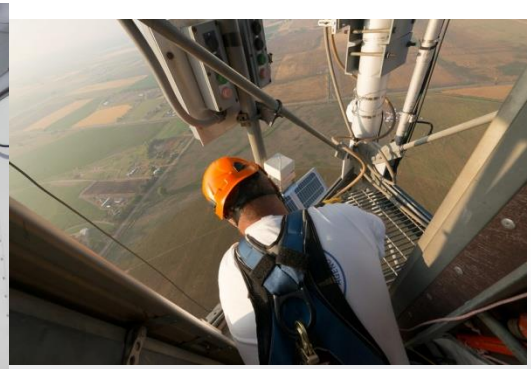


Points of Contact:
ORD: Russell Long, Rachelle Duvall

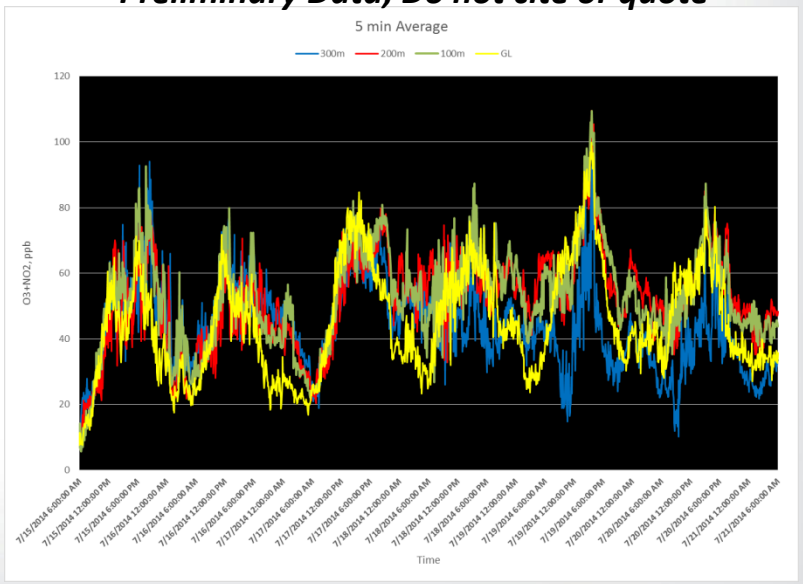
Sensor performance evaluation: lab and field

DISCOVER-AQ Study Denver, CO (Jul-Aug 2014)

- Sensors collocated with FRM/FEM measurements
- Citizen science sites
- Understanding vertical distribution of pollutants



Preliminary Data; Do not cite or quote



Sensor System Development

Solar-powered, air and meteorological monitoring bench

- Sustainable Materials: Manufactured from recycled milk jugs
- Tamper-proof: Instruments secured in bench or base of play structure
- Designed to add value to public environments (bench)
- Formal agreement with Durham County on collaboration

Points of Contact: Gayle Hagler, Ron Williams

Sensor System Development

EPA Village Green Project

Air instruments (PM, ozone), power system and communications components stored securely behind bench

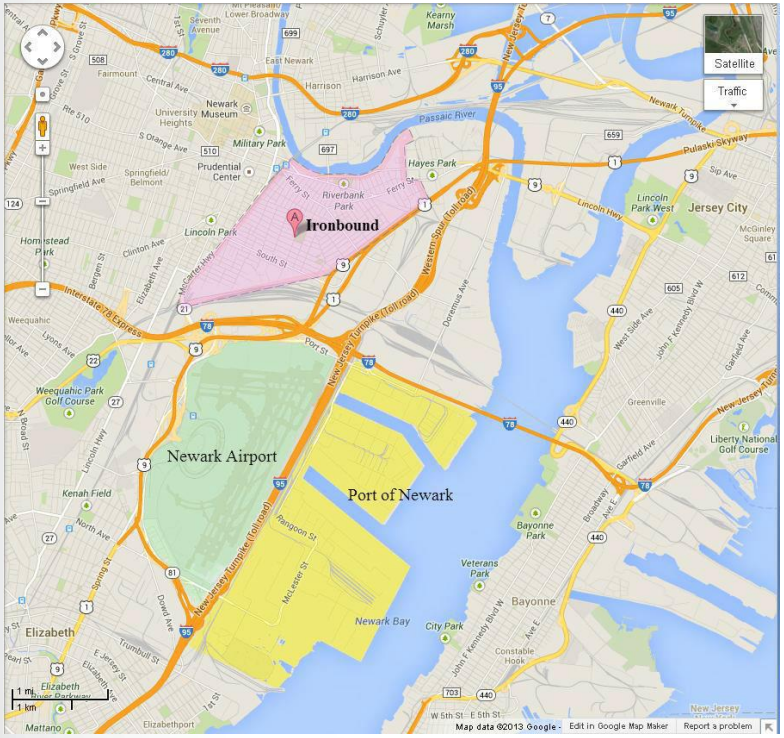
Sensor System Development

Website: http://villagegreen.epa.gov/

Sensor System Development

Region 2 / ORD RARE Project – Citizen Science Toolkit and the Ironbound Community Corporation

Ironbound community



- Bound by: highways, waterways, railroads, Newark Airport, Port Newark/Elizabeth

Objectives:

- Advance use of sensor technologies
- Develop specific Tool Box for Citizen Science (e.g. SOP for sensors, guidance on deployment, ideas for data analysis, interpretation and communication)
- Identify pollutants of interest, appropriate sensors, deployment strategies, and data interpretation and communication methods
- Promote citizens being involved in areas associated with environmental education and awareness
- Work collaboratively with R2 as test case for other Regions to consider
- Investigate feasibility of regional-led sensor loan program

Points of Contact:
R2: Anhthu Hoang
ORD: Tim Barzyk, Ron Williams

Sensor System Development

Regional Methods Project – CAIRSENSE Community Air Sensor Network

- Long term evaluation of low-cost sensors at regulatory site in Atlanta, GA
- Installation of 4-node multipollutant wireless sensor network surrounding the regulatory site

Key Collaborators

Region 4 – Lead
Region 5
Region 8
Region 1
OAR
ORD

Schedule / Location:

Year 1: Atlanta area installation starting Summer 2014
Year 2: Denver-area installation around Summer 2015

Pollutant prioritization (per Regions):

1) NAAQs
2) Air Toxics
3) Other: source indicators / climate-related

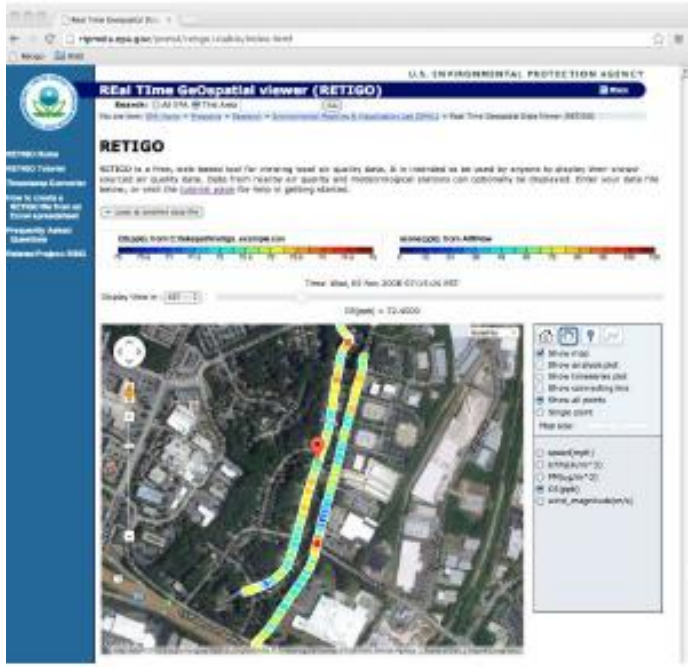
Points of Contact:
R4: Ryan Brown, Daniel Garver
ORD: Gayle Hagler, Ron Williams

Data Visualization support: RETIGO

Objective: reduce barriers to participating in mobile air monitoring data analysis

Mobile Air Monitoring Data:
- Function of time, location, and pollutant
- Often collected at a high time resolution (large time series)
- Variable format, location, instruments

Mobile Air Monitoring data analysis and exploration:
- Analysis often limited to those individuals with advance training and access to specific software tools (e.g. MATLAB, GIS, etc.)



We are building RETIGO to support mobile air monitoring individuals and teams, reducing the technical barriers to visualize the complex data and complement advanced data analysis techniques.

Point of Contact:
ORD: Gayle Hagler

What does this all mean?

Current Approach

Sensor Technology

New Paradigm

	Current Approach	New Paradigm
Who Collects the data?	Limited Mostly to Governments, Industry, and Researchers	Expanded Use by Communities and Individuals
Why data is collected?	Compliance Monitoring, Enforcement, Trends, Research	New Applications and Enhancement of Existing Applications
How data is accessed?	Government Websites, Permit Records, Research Databases	Increased Data Availability and Access

Snyder et al., 2013

Ongoing and Future Work at EPA

- Field and laboratory research to characterize performance of sensors (new PM, VOC, O_3, NO_2, SO_2 and others)
- Development of tools for managing and visualizing sensor data
- Ongoing dialogue on policy implications and public health messaging
- Updated market/literature surveys
- Pursue new MCRADAs
- Expansion of Village Green deployments
- Citizen tool box opportunities

Acknowledgments

EPA ORD staff: Gayle Hagler, Ron Williams, Eben Thoma, Brian Gullet, Russell Long, Melinda Beaver, Eric Hall, Bill Mitchell, Bill Squier, Tim Watkins, Lindsay Stanek, Vasu Kilaru, Paul Solomon, Stacey Katz, Gail Robarge, Peter Preuss, Emily Snyder, Ann Brown, Kelly Leovic

Postdocs, student service contractors and interns: Wan Jiao, Xiaochi Zhou, Dana Buchbinder*, Rachel Clark*, Amanda Kaufman, Karoline Johnson* (*now in new positions)

Additional Resources

EPA Next Generation Air Monitoring

http://www.epa.gov/research/airscience/next-generation-air-measuring.htm